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Performance Comparison of IEEE 802.11e EDCA and 802.11b DCF Under Non-Saturation Condition using Network Simulator

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Abstract: In this study, throughput and delay performance of IEEE 802.11b and 802.11e is presented under non-saturation conditions. In order to improve the performance of IEEE 802.11b, the IEEE 802.11e has been proposed to improve the Quality of Services (QoS) for multimedia application. The standard 802.11b CSMA/CA contention mechanism does not support QoS but the standard 802.11e provides QoS by adjustment of MAC parameters. The comparison of 802.11b DCF and 802.11e EDCA mechanism by using Network Simulator (NS-2) with different parameters such as throughput, delay, CW_{min} and AIFS differentiation are simulated. The EDCA stations have more competitive advantages than 802.11b under all the above parameters. The simulation results show that the proposed algorithm improves the performance of the EDCA stations.

Keywords: DCF and EDCA, IEEE 802.11, non-saturation, WLAN

INTRODUCTION

IEEE 802.11 Wireless Local Area Network (WLAN) (IEEE Standard 802.11, 1999) is one of the most widely deployed wireless network technologies in the world today. Distributed Coordination Function (DCF) and Enhanced Distributed Channel Access (EDCA) are the fundamental access mechanisms for IEEE 802.1b and IEEE 802.11e (IEEE Standard 802.11, 1999; IEEE Standard 802.11, 2005) respectively. The DCF and EDCA implement a Binary Exponential Backoff (BEB) algorithm by increasing the contention window size exponentially for each transmission failure for collision is resolved (IEEE Standard 802.11, 1999; IEEE Standard 802.11, 2005; Bianchi, 2000). Therefore, the focus of this study is to modify BEB for improving the performance of DCF and EDCA stations using network simulator (NS 2 version 2.29). Many researchers have done individually by study of IEEE 802.11 DCF and EDCA performance in both analytically and simulation. Most of them assumed as an ideal channel condition, which means that the packet corruptions are only due to collision (Bianchi, 2000; Vassis and Kormentzas, 2005; Kong *et al*., 2004). But few of them assumed that non ideal channel condition which means that packet collision due to noise (Dhanasekaran and Krishnan, 2010; Daneshgaran *et al*., 2008). Previous researches of our study (Prakash and Thangaraj, 2011a; Prakash and Thangaraj, 2011b; Prakash and Thangaraj, 2010) have analyzed non-saturation throughput performance of the IEEE 802.11 DCF and EDCA in the presence of transmission error, but few of them done comparison of DCF and EDCA under non saturation traffic condition.

In real network, traffic is mostly non-saturation (mobile stations have not always packet to transmit). In this study, we extend the previous studies for the comparison of DCF and EDCA with different parameters such as number of stations, CW_{min} differentiation, throughput, media access delay and AIFS differentiation. We invite the interested reader to refer the basics of DCF and EDCA of IEEE 802.11 is presented in Prakash and Thangaraj, (2011b) Prakash and Thangaraj, (2010) Prakash and Thangaraj (2011c) and Kong *et al*., (2004). The simulator considers an Infrastructure BSS (Basic Service Set) with an AP and a certain number of mobile stations which communicates only with the AP. For simplicity, we assume that data packets transmitted by different stations are involved by the same probability of error. This way, channel errors on the transmitted packets can be accounted for as it is done within ns-2 (network simulator-ns-2, 2010). The simulation results show that the proposed scheme provides a remarkable performance improvement in WLAN environments.

MATERIALS AND METHODS

The detailed differences between DCF and EDCA: The DCF is designed for best-effort data transmission by using Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA). The DCF scheme does not provide any

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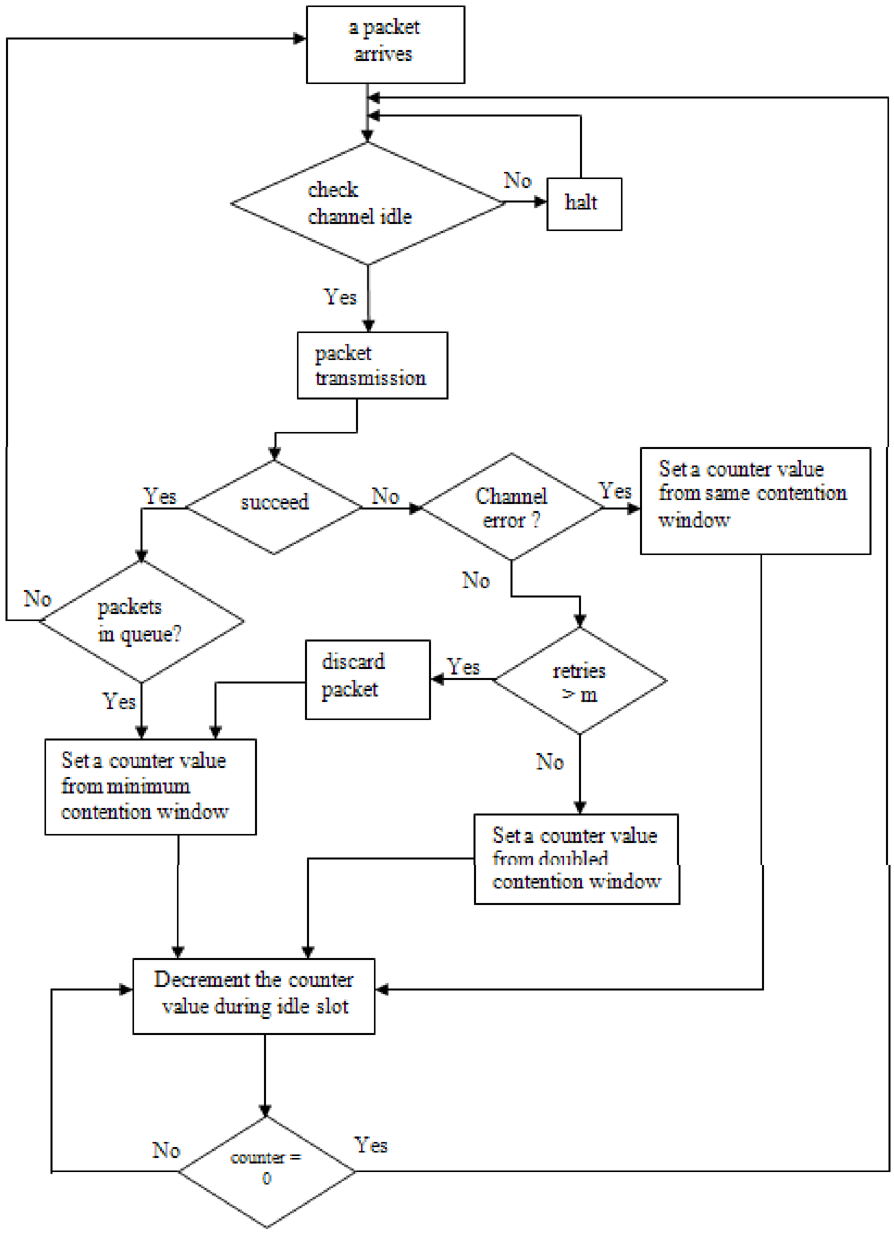

Fig. 1: Proposed binary exponential backoff workflow for IEEE 802.11b DCF

means of service differentiation and thus assumes that all flows have equal priority. The main concern of DCF is to reduce the collision among the flows that are competing for access to the wireless medium. In DCF, the backoff counter is decremented at the end of each slot following DIFS. On the other hand, the backoff counter is decremented after AIFS has passed in EDCA scheme (Hwang and Cho, 2006; Majkowski and Palacio, 2006; Bianchi *et al*., 2005). In DCF, a transmission can begin if backoff counter makes a transition to 0 and the medium is idle. Differently, EDCA station can transmit only if a backoff value is already 0. In EDCA, the backoff counter can be decremented or the station starts Rx toTx turnaround when backoff counter value is zero.

While DCF and PCF schemes were not able to fulfill the QoS requirements for multimedia applications. DCF is simple and allocate wireless medium access to all flows in the same manner. PCF, though it includes service differentiation mechanisms, it still considers all flows from a specific station to have the same priority.

Therefore, the 802.11e WLAN standard has introduced the Enhanced Distributed Channel Access (EDCA), which adds transmission prioritization to CSMA/CA. EDCA is a completely distributed scheme and allows each station to sort its traffic in four different Access Categories (AC) (Kong *et al*., 2004; Engelstad and Osterbo, 2005; Xiao, 2005; Qiang, 2005; Vassis and Kormentzas, 2005). By doing this, EDCA provides service differentiation, taking into consideration the various needs of flows within a specific station. As such, EDCA could be considered as the new version of the legacy DCF.

Modified backoff work flow: In this study, we modified the binary exponential backoff algorithm for the case of transmission or channel error. In the noisy wireless environment, without distinguish packet collision and channel error, the DCF cannot adjust the backoff procedure properly. To resolve this problem, we present new backoff algorithm. When a collision occurs, the backoff time of the collided stations are doubled to reduce the contention. When there is a channel error due to channel noise, instead of doubling the contention window as in the standard, the station select the backoff time from the same contention window. Simulations results show that the new backoff algorithm working significantly improve the throughput in WLAN. Therefore the backoff algorithm will cause long delay and poor channel utilization when there are successive transmission errors. This backoff algorithm is explained in the flow chart shown in Fig. 1.

Another effective modification of the EDCA has been proposed in the event of transmission errors. In the basic AC, the contention window is doubled after every unsuccessful transmission. Unsuccessful transmission happens in two cases:

- Internal collision or virtual collision of a packet with other packets with in a station
- Due to error in the channel or packet collision with other station

Here the internal collision refers to the collision among the queues of different priorities inside a station, while the external collision refers to that among different stations. We proposed Binary Exponential Backoff workflow for IEEE 802.11e EDCA for considering internal collision and erroneous transmission under non-saturation traffic conditions, instead of doubling the contention window in the internal collision the backoff counter selects a counter value from the same contention window. This backoff algorithm is explained in the flow chart shown in Fig. 2. We consider a WLAN in Unsaturation (Nonsaturation) condition, that is buffer of the transmitting station is empty, after a successful transmission.

CW_{min} and AIFS differentiation: EDCA is designed to provide prioritized QoS by enhancing the contention-based DCF. Before entering the MAC layer, each data packet received from the higher layer is assigned a specific user priority value. EDCA introduces four different First-In First-Out (FIFO) queues, called Access Categories (ACs). Each data packet from the higher layer along with a specific user priority value should be mapped into a corresponding AC according to a Table 1 (Hwang and Cho, 2006; Majkowski and Palacio, 2006; Bianchi *et al*., 2005). Different kinds of applications (e.g., background traffic, best effort traffic, video traffic and voice traffic) can be directed into different ACs. Each AC behaves as a single DCF contending entity with its own contention parameters ($CW_{min}[AC]$, $CW_{max}[AC]$, $AIFS[AC]$ and $TXOPLimit[AC]$), which are announced by the QAP periodically in beacon frames.

The CW_{min} differentiation employed in EDCA is to change the amount of TXOPs provided to each traffic class. A station with a lower value of CW will reduce the average time needed to successfully deliver a packet and thus experience improved performance in comparison to stations with higher CW values. The average value of the CW can be tuned through differentiated setting of the backoff parameters and specifically of CW_{min} and CW_{max}.

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AIFS differentiation is to reserve channel slots for the access of higher-priority stations. This is accomplished by using different AIFS values for different traffic classes. The AIFS is the amount of time a station defers access to the channel following a busy channel period. Once an AIFS has elapsed, the station access is managed by the normal backoff rules (Hwang and Cho, 2006; Majkowski and Palacio, 2006; Bianchi *et al*., 2005).

A basic issue of AIFS differentiation is that confined slots occur after every busy channel period. This implies that the percentage of confined slots significantly increases as long as network congestion increases. In reality, a greater number of competing stations involves that the average number of slots between consecutive busy channel periods reduces and thus the fraction of protected slots over the total number of idle slots gets larger.

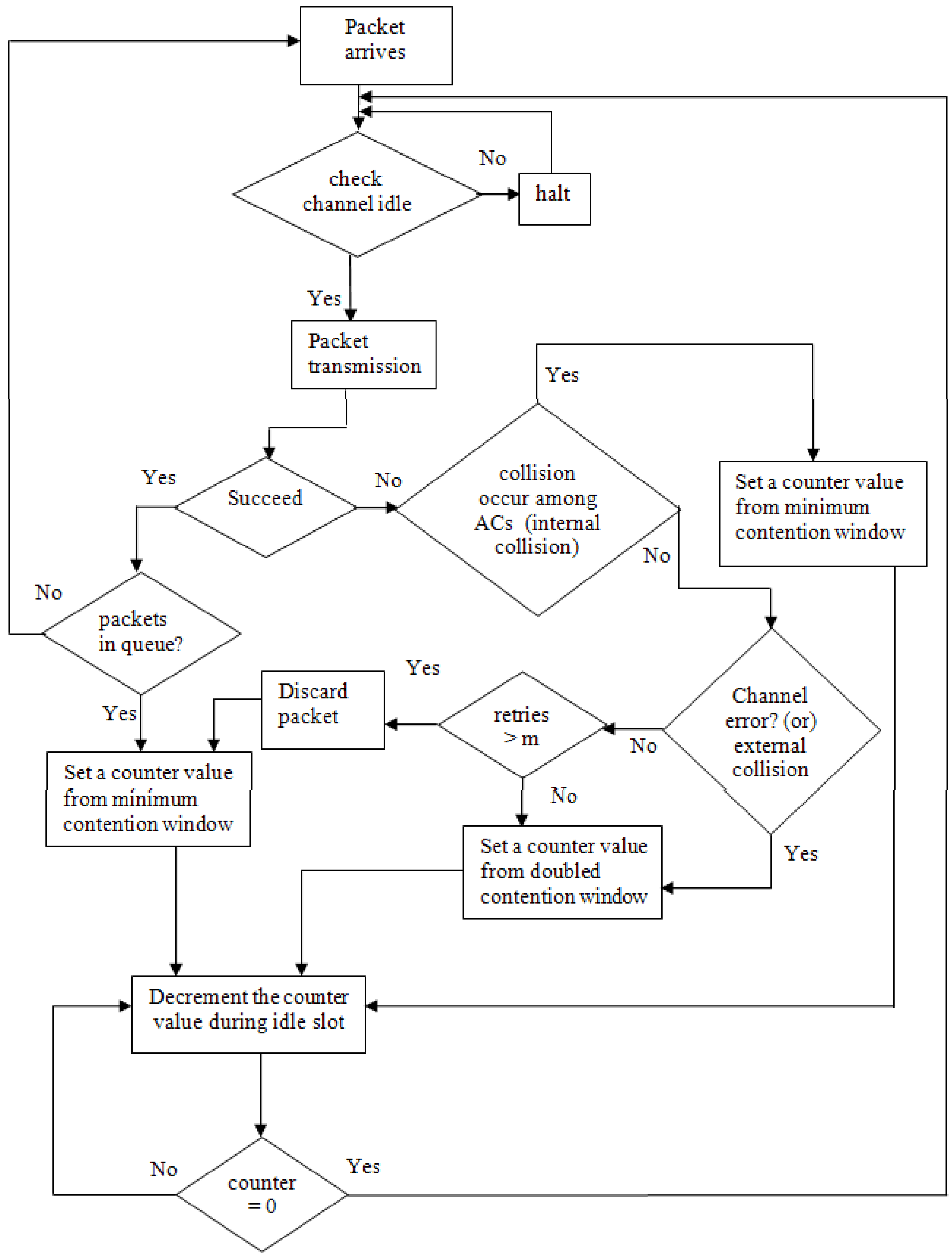

Fig. 2: Proposed binary exponential backoff workflow for IEEE 802.11e EDCA

Table 1: Default parameters for EDCA

	Voice	Video	Background (best effort)
Transport protoco	lUDP	UDP	UDP
AC	VO	VI	BE
CW_{min}	3	7	15
CW_{max}	7	15	1023
AIFSN	2	2	3
Packet size	160 bytes	1280 bytes	1500 bytes
Packet interval	20 ms	10 ms	12.5 ms
Sending rate	64 kb/s	1024 kb/s	960 kb/s

SIMULATION RESULTS OF DCF AND EDCA

Wireless Local Area Network (WLAN) consists of two different set of STAs, one set of STAs is running under IEEE 802.11b MAC protocol and another set of STAs is running under IEEE 802.11e MAC protocol. EDCA stations have been configured with the standard DCF backoff parameters (CW_{min} = 31 and CW_{max} = 1023). The packet size has been fixed to 1024 bytes and the

Table 2: EDCA default settings

Access category	CW_{min}	CW_{max}	AIFSN
AC_BK	aCW_{min}	aCW_{max}	7
AC_BE	aCW_{min}	aCW_{max}	3
AC_VI	$aCW_{min}/2$	aCW_{min}	2
AC_VO	$aCW_{min}/4$	$aCW_{min}/2$	2

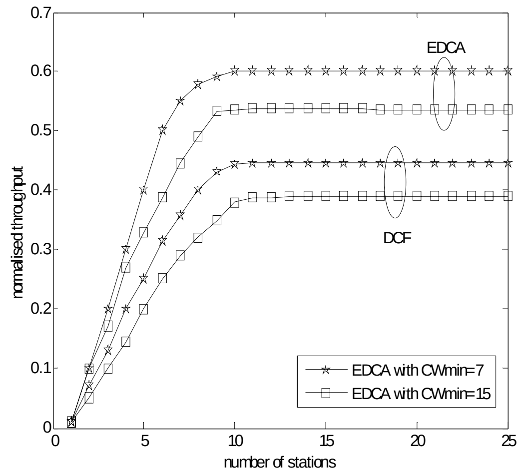

Fig. 3: DCF vs. EDCA throughput with CW_{min} differentiation

retransmission limit is set to 7 for all the stations. Control frames are transmitted at a basic rate equal to 1 Mbps, while the MAC Protocol Data Unit is transmitted at 2 Mbps. Table 2 shows the default values of the channel access parameters defined in EDCA for the four ACs (BK = background, BE = best effort, VI = video, VO = voice). In order to be granted priority over the DCF stations, EDCA must be configured with CW_{min} values smaller than the legacy DCF value CW_{min} = 31. The Network Simulator NS-2.29 version (network simulator-ns-2, 2008) is used for simulation.

Figure 3 shows that for low values of number of stations (n), the involvement between EDCA and DCF stations is contrariwise related to the employed CW_{min} value. For example, in the case of $n = 10$, the throughput performance of EDCA when $CW_{min} = 7$ is about double times the corresponding throughput performance of DCF (which uses $CW_{min} = 31$); similarly, when $CW_{min} = 15$, it is about double the DCF throughput. In general, the throughput performance of EDCA is proves better performance result as shown in the Fig. 3. As the number of competing stations grows, the EDCA throughput significantly reduces, while the DCF also decreases.

Figure 4 shows that comparison of DCF and EDCA throughput with *AIFS* differentiation simulation results for AIFSN = 1, 2, 3 and DCF stations coexist as the number of station for each scheme increases. As the number of stations for each scheme increases, the difference of throughput also increases because more EDCA stations get chances to transmit a packet due to one decrement of backoff counter at the end of AIFS after every

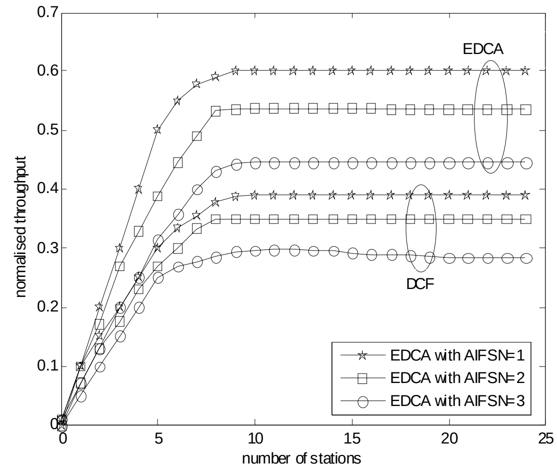

Fig. 4: DCF vs. EDCA throughput with *AIFS* differentiation

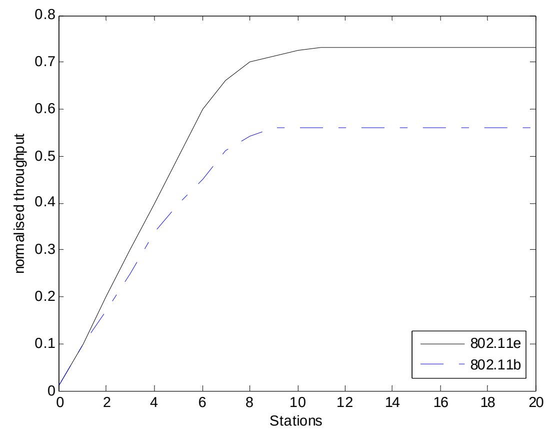

Fig. 5: Throughput comparisons for DCF vs. EDCA stations

transmission. The total throughput decreases as the number of stations increases, which is a consequence of increased collisions

Figure 5 presents the throughput result and reconfirms that 802.11e provides remarkably improved throughput in comparison to 802.11. In Fig. 5 shows that EDCA has enhanced throughput when compare to DCF, because the 802.11e stations have a high priority to transmits a packet than DCF stations.

Figure 6 shows that throughput with different ACs for EDCA and DCF stations. We observe that throughput of EDCA stations for voice and video traffic is abnormally improved as compared to 802.11b.The throughput increases for higher priority (voice and video) and low throughput for low priority (best effort and background). It shows that throughput for all four traffic streams starts to drop equally as the sixth and eighth stations are added to the network in 802.11. On the other hand, 802.11e provides traffic prioritization (voice and video) through its service differentiation mechanism. The

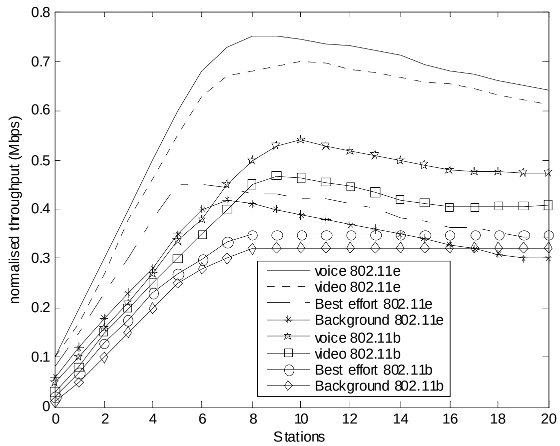

Fig. 6: Throughput comparisons with different access categories for DCF and EDCA

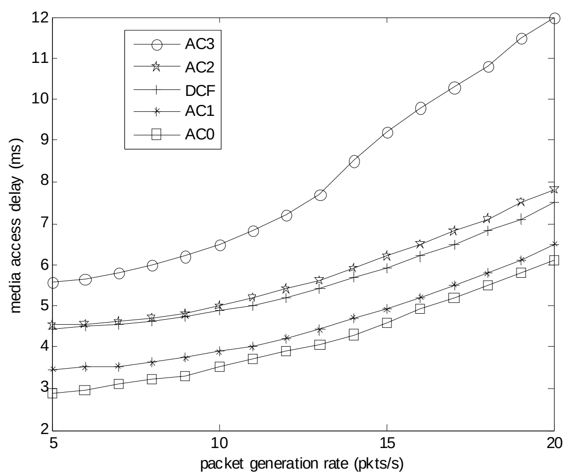

Fig. 7: Media access delay versus packet generation rate

throughput decreases for best effort and background traffic streams in 802.11e compared to 802.11b stations. Finally, the comparison shows that 802.11e offers improved service to higher priority traffic than low priority traffic which is poor performance than 802.11b. In addition the throughput versus stations for different access categories comparison with DCF stations. We observe that EDCA is effective in providing service differentiation in terms of throughput, higher priority AC's always perform better than lower priority ones.

In addition to higher priority AC's gets saturates after, AC's 0 and 1 (voice and video) saturates for n>6 with higher throughput, while AC's 2 and 3 (Best effort and background) saturate for n>8. From this figure the throughput of DCF is significantly increases with AC's 2 and 3 priorities station.

Figure 7 show the media access delay versus the packet generation rate for a random station of each ACs

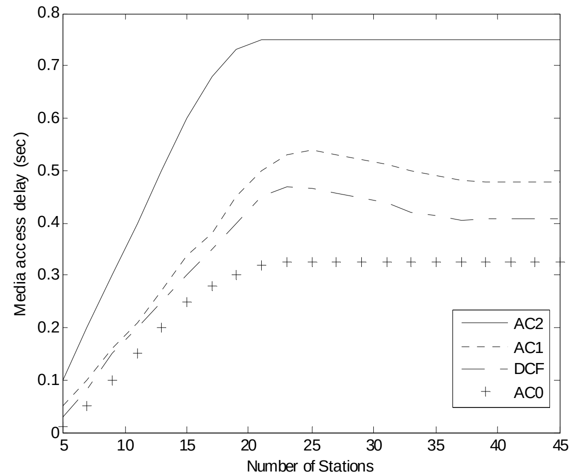

Fig. 8: Media access delay versus the number of stations in non-saturation

and compared with DCF. We observe that the medium access delay for the middle priority stations (AC-2) is very close values of DCF case. This means that the enhancement in the delay for high priority stations. Furthermore, the MAC delay increase for all ACs after 10 (pkts/sec). But delays in high priority (AC 0 and AC1) have significant improvement.

Figure 8 shows the non-saturation delay versus the number of stations for different access categories with DCF. High priority classes have a small media access delay that has a significant impact in the low priority classes. Middle priority classes are not affected. As it is shown, the increase in the traffic of AC-2 stations affects mostlyAC-0 stations. AC-1 stations have a similar performance to that of the DCF case and AC-2 stations obviously perform better than in the DCF case.

CONCLUSION

This research present study on performance of 802.11b DCF and 802.11e EDCA. The contention-based EDCA mechanism can provide effective service differentiation between different types of traffic. The performance is measured by non-saturation traffic conditions. The simulation output is shown that EDCA scheme has much better performance over DCF stations especially at low traffic load. Since EDCA stations get more chances to transmit a packet due to one decrement of backoff counter at the end of AIFS after every transmission. The total throughput decreases as the number of stations increases, which is a consequence of increased collisions. The Network Simulator (NS-2.29) tool is used for simulation. Analysis of jitter and delay-control will be investigated for the future study.

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